copper, and Y is the percent, by weight, of silicon; and the copper alloy has a metal construction comprising multiple phases integrated to form a composite phase, wherein the composite phase is an α phase matrix having a total phase area comprising not more than 5% of a β phase, and 5-70% of the total phase area is provided by at least one phase selected from the group consisting of a γ phase, a κ phase, and a μ phase. This second copper alloy will be hereinafter called the "second invention alloy."

[0018] That is, the second invention alloy is composed of the first invention alloy and, in addition, one element selected from among 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium, and 0.02 to 0.4 percent, by weight, of selenium.

[0019] Bismuth, tellurium, and selenium, as with lead, do not form a solid solution with the matrix but disperse in granular form to enhance machinability. That makes up for the reduction of the lead content. The addition of any one of those elements along with silicon and lead could further improve the machinability beyond the level obtained from the addition of silicon and lead. From this finding, the second invention alloy was developed, in which one element selected from among bismuth, tellurium, and selenium is mixed. The addition of bismuth, tellurium, or selenium as well as silicon and lead can make the copper alloy so machinable that complicated forms can be freely cut out at a high speed. But no improvement in machinability can be realized from the addition of bismuth, tellurium, or selenium in an amount of less than 0.02 percent by weight. However, those elements are expensive as compared with copper. Even if the addition exceeds 0.4 percent by weight, the proportional improvement in machinability is so small that addition beyond that level does not pay off economically. What is more, if the addition is more than 0.4 percent by weight, the alloy will deteriorate in hot workability such as forgeability and cold workability such as ductility.

While there might be a concern that heavy metals like bismuth would cause a problem similar to that of lead, a very small addition of less than 0.4 percent by weight is negligible and would present no particular problems. From those considerations, the second invention alloy is prepared with the addition of bismuth, tellurium, or selenium kept to 0.02 to 0.4 percent by weight. In this regard, it is desired to keep the combined content of lead and bismuth, tellurium, or selenium to not higher than 0.4 percent by weight. That is because if the combined content exceeds 0.4 percent by weight, if slightly, then there will begin a deterioration in hot workability and cold ductility and also there is fear that the form of chippings will change from (B) to (A) in Fig. 1. But the addition of bismuth, tellurium or selenium, which improves the machinability of the copper alloy though a mechanism different from that of silicon as mentioned above, would not affect the proper contents of copper and silicon. For this reason, the contents of copper and silicon in the second invention alloy are set at the same level as those in the first invention alloy.

[0020] Another embodiment of the present invention is a free-cutting copper alloy, also with an excellent easy-to-cut feature, which is composed of 70 to 80 percent, by weight, of copper; 1.8 to 3.5 percent, by weight, of silicon; 0.02 to 0.4 percent. by weight, of lead; at least one element selected from among 1.0 to 3.5 percent, by weight, of aluminum, and 0.02 to 0.25 percent, by weight, of phosphorus; and the remaining percent, by weight, of zinc, wherein the percent by weight of copper, silicon, aluminum and phosphorus in the copper alloy satisfy the relationship $60 \leq X - 3Y + aZ + bW \leq 70$, wherein X is the percent, by weight, of copper, Y is the percent, by weight, of silicon, Z is the percent, by weight, of aluminum, W is the percent, by weight, of phosphorus, a is –2, and b is -3; and the copper alloy has a metal construction comprising multiple phases integrated to form a composite phase, wherein the

composite phase is an α phase matrix having a total phase area comprising not more than 5% of a β phase, and 5-70% of the total phase area is provided by at least one phase selected from the group consisting of a γ phase, a κ phase, and a μ phase. This third copper alloy will be hereinafter called the "third invention alloy."

[0021] Aluminum is effective in facilitating the formation of the gamma phase and works like silicon. That is, if aluminum is added, a gamma phase will be formed and this gamma phase improves the machinability of the Cu-Si-Zn alloy. Aluminum is also effective in improving the strength, wear resistance, and high-temperature oxidation resistance as well as the machinability of the Cu-Si-Zn alloy. Aluminum also helps keep down the specific gravity. If the machinability is to be improved at all, aluminum will have to be added in an amount of at least 1.0 percent by weight. But the addition of more than 3.5 percent by weight could not produce proportional results. Instead, adding more aluminum in excess of 3.5 percent by weight lowers the ductility of the metal alloy without contributing further to the machinability.

[0022] As to phosphorus, it has no property of forming the gamma phase as does aluminum. But phosphorus works to uniformly disperse and distribute the gamma phase formed as a result of the addition of silicon alone or with aluminum. That way, the machinability improvement through the formation of gamma phase is further enhanced. In addition to dispersing the gamma phase, phosphorus helps refine the crystal grains in the alpha phase in the matrix, improving hot workability and also strength and resistance to stress corrosion cracking. Furthermore, phosphorus substantially increases the flow of molten metal in casting. To produce such results, phosphorus will have to be added in an amount not smaller than 0.02 percent by weight. But if the addition exceeds 0.25